An eGovernment system for temporal- and semantic-aware access to norms

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Abstract

In this paper, we present the results of an ongoing research involving the design and implementation, in an eGovernment scenario, of a semantic-aware system supporting efficient and personalized access to a multi-version repository of normative texts. The research activity is entitled "Semantic web techniques for the management of digital identity and the access to norms". In the context of a complete and modular infrastructure, we defined a multi-version XML data model and developed a temporal and semantical XML query processor supporting both temporal versioning –essential in normative systems– and semantic versioning. Semantic versioning is based on the applicability of different norm parts to different classes of citizens and allows users to retrieve personalized norm versions only containing provisions which are applicable to their personal case. The whole infrastructure, which we plan to complete in the near future, will integrate the querying component with several auxiliary services, including automatic citizen identification and classification and assisted update of the repository data.

Introduction

Nowadays we are witnessing a strong institutional push towards the implementation of eGovernment support services, aimed at a higher level of integration and involvement of the citizens in the Public Administration (PA) activities that concern them. In this framework, collections of norm texts and legal information presented to citizens are made available in XML format (XML 2005) and are becoming popular on the internet. The offering of personalized versions is aimed at improving and optimizing the involvement of citizens in the eGovernance process. In existing systems, personalization is either absent (e.g. (NIR 2005)) or predefined by human experts and hardwired in the repository structure (e.g. (EGov.it 2005)), whereas flexible and on-demand personalization services are lacking.

In this challenging scenario, takes its place the research activity entitled "Semantic web techniques for the management of digital identity and the access to norms", which we are carrying out as part of the PRIN Italian project "European Citizen in eGovernance: legal-philosophical, legal, computer science and economical aspects" (PRIN Project

2003). One of the main objectives of such activity is the development of a system allowing an effective and efficient access to multi-version norm repositories supporting temporal queries and personalization facilities. Personalization is based on possible limitations in the applicability of norm provisions and takes into account the identity of the user as a citizen subject to norms. With the term "norm" we mean documents that articulate some law or policy. Indeed, the fast dynamics involved in normative systems implies the coexistence of multiple *temporal versions* of the normative texts stored in a repository, since laws are continually subject to amendments and modifications (for instance, it is crucial to reconstruct the consolidated version of a norm as produced by the application of all the modifications it underwent so far). Moreover, another kind of versioning plays an important role, because some norms or some of their parts have or acquire a limited applicability. For example, a given norm may contain some articles which are only applicable to particular classes of citizens (e.g. public employees). Hence, a citizen accessing the repository may be interested in finding a *personalized version* of the norm, that is a version only containing articles which are applicable to his/her personal case.

Fig. 1 shows the complete infrastructure, along with its different components, we envisioned in order to achieve the above mentioned goals (Grandi *et al.* 2004). Firstly, in order to obtain a personalized access, a secure *authentication* is required for a citizen accessing the infrastructure. This is performed through a simple elaboration unit, also acting as user interface, which processes the citizen's requests and manages the results. Then, in order to enhance the participation of the citizens to an eGovernance procedure of interest, their automatic and accurate positioning within the reference legal framework is needed. To solve this problem we employ Semantic Web techniques and introduce a *civic ontology* (O_C in Fig. 1), which corresponds to a classification of citizens based on the distinctions introduced by subsequent norms which imply some limitation (total or partial) in their applicability. In the following, we refer to such norms as *founding acts*. Moreover, we define the citizen's *digital identity* as the total amount of information concerning him/her –necessary for the sake of classification with respect to the ontology– which is available online (Rodotà 2001). Such information must be retrievable in an automatic, se-
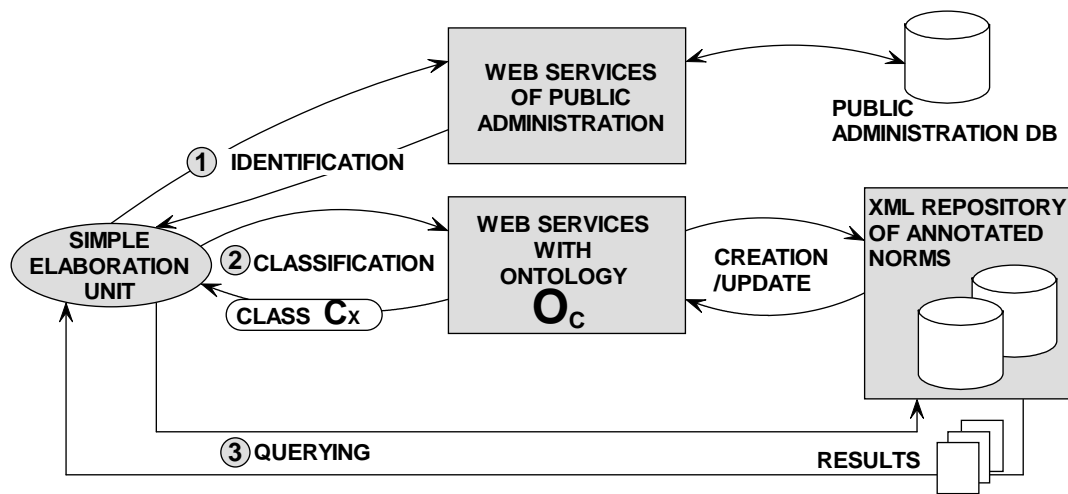
Figure 1: The Complete Infrastructure

cure and reliable way from the PA databases through suitable Web services and is exploited in the following phases:

- the **identification phase** (step 1 in Fig. 1) consists of calls to identification services to reconstruct the digital identity of the authenticated user on-the-fly. In this phase the system collects pieces of information from all the involved PA web services and composes the identity of the citizen.

- the citizen **classification phase** (step 2 in Fig. 1) in which the classification service uses the collected digital identity to classify the citizen with respect to the civic ontology, by means of an embedded reasoning service. In Fig. 1, the most specific class C_X has been assigned to the citizen;

- finally, in the **querying phase** (step 3 in Fig. 1) the citizen's query is executed on the multi-version XML repository, by accessing and reconstructing the appropriate version of all and only norms which are applicable to the class C_X.

In order to supply the desired services, the digital identity is modelled and represented within the system in a form such that it can be translated into the same language used for the ontology (e.g. a Description Logic (Baader, Horrocks, & Sattler 2002)). In this way, during the classification procedure, the matching between the civic ontology classes and the citizen's digital identity can be reduced to a standard reasoning task (e.g. ontology entailment for the underlying Description Logic (Horrocks & Patel-Schneider 2003)). Furthermore, the civic ontology used in steps 2 and 3 requires to be created and constantly maintained: each time a new founding act is enforced, the execution of a **creation/update phase** is needed. Notice that this process (and also the introduction of semantic annotations into the multi-version XML documents) is a delicate task which needs advice by human experts and "official validation" of the outcomes and, thus, it can only partially be automated. However, computer tools and graphic environments (e.g. based on the Protégé platform (OWL Plugin 2005)) could be provided to assist the human experts to perform this task.

For the specification of the identification, classification and creation/update services, we plan to adopt a standard declarative formalism (e.g. based on XML/SOAP (SOAP 2005)).

This section introduces the current achievements of our research activity and presents in detail the complete infrastructure of our system. The section which follows investigates the aspects of selective and personalized access to multi-version documents. The section coming next is devoted to the implementation and assessment of a prototype of the document repository and query processor. Finally, we conclude the paper with a discussion on achievements and future work.

Personalized access to norms

Up to now, our research has been mainly focused on the querying phase. In particular, we defined an XML data model which combines semantic annotations with temporal versioning and we defined efficient techniques for querying repositories storing legal documents supporting temporal and semantic versioning.

Temporal concerns are widespread in the eGovernment domain and a legal information system should be able to retrieve or reconstruct on demand any version of a given document to meet common application requirements. In fact, whereas it is crucial to reconstruct the current (consolidated) version of a norm as it is the one that currently belongs to the regulations and must be enforced today, also past versions are still important, not only for historical reasons. For example, if a Court has to pass judgment today on some fact committed in the past, the version of norms which must be applied to the case is the one that was in force then. We then extend the temporal framework with semantic versioning in order to provide personalized access to normative texts. Semantic versioning also plays an important role, due to the limited applicability that norms or some of their parts have or acquire. Hence, it is crucial to maintain the mapping between each portion of a norm and the maximal class
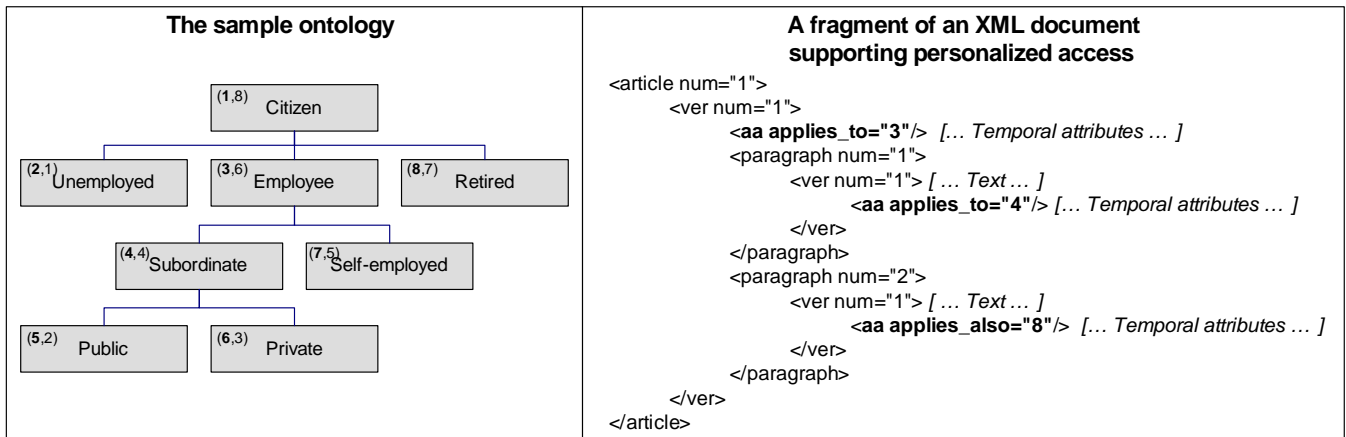
Figure 2: An example of civic ontology, where each class has a name and is associated to a (pre,post) pair, and a fragment of a XML norm containing applicability annotations.

of citizens it applies to in order to support an effective personalization service. The norms are translated in our multi-version XML data model through a semi-automated process involving a human expert by means of an "intelligent" interactive editor, to be used for marking-up norms with temporal and semantic attributes and recording the new laws in legal databases (Palmirani & Brighi 2002). Temporal and semantic versioning are detailed in the next subsections.

Temporal Versioning

We first focused on the temporal aspects and on the effective and efficient management of time-varying normative texts. Our work on these aspects is based on our previous research experiences (Grandi *et al.* 2003; Grandi, Mandreoli, & Tiberio 2005). To this purpose, we developed a temporal XML data model which uses four time dimensions to correctly represent the evolution of norms in time and their resulting versioning. The considered dimensions are:

Validity time. It is the time the norm is in force. It has the same semantics of valid time as in temporal databases (Jensen, Dyreson, & others 1998), since it represents the time the norm actually belongs to the regulations in the real world.

Efficacy time. It is the time the norm can be applied to concrete cases. While such cases do exist, the norm continues its efficacy even if no longer in force. It also has a semantics of valid time although it is *independent* from validity time.

Transaction time. It is the time the norm is stored in a computer system. It has the same semantics of transaction time as in temporal databases (Jensen, Dyreson, & others 1998).

Publication time. It is the time of publication of the norm on the Official Journal. It has the same semantics as event time in temporal databases (Kim & Chakravarthy 1993). As a global and unchangeable norm property, it is not used as a versioning dimension.

The data model was defined via an XML Schema (XML Schema 2005), where the structure of norms is defined by means of a contents-section-article-paragraph hierarchy and multiple content versions can be defined at each level of the hierarchy. Each version is characterized by timestamp attributes defining its temporal pertinence with respect to each of the validity, efficacy and transaction time dimensions. The model is also equipped with two basic operators for the management of norm modifications: one is devoted to change the textual content of a norm portion and the other allows modifications to the temporal pertinence of a given version. The former can be used for deletion of (a part of) the norm (abrogation), or the introduction of a new part of the norm (integration), or the replacement of (a part of) the norm (substitution). The latter can be used to deal with the time extension or the suspension of (part of) the norm. Details can be found in (Grandi *et al.* 2003; Grandi, Mandreoli, & Tiberio 2005).

Legal text repositories are usually managed by traditional information retrieval systems where users are allowed to access their contents by means of keyword-based queries expressing the subjects they are interested in. Advanced systems (e.g. Norma-system (Palmirani & Brighi 2002)) allow users to reconstruct a consistent version of the retrieved norm with respect to validity (consolidated act). We extended such a framework by offering users the possibility of expressing temporal specifications for the reconstruction of a consistent version of the retrieved normative acts with respect to all time dimensions.

Starting from a first implementation of our temporal model, which is described in (Grandi *et al.* 2003; Grandi, Mandreoli, & Tiberio 2005), we deeply redesigned the overall system architecture, the document storage scheme and the query processing methods in order to improve efficiency. The redesign also took into account the new problems arising from the extension to support semantic versioning. The new system organization, introduced in (Grandi *et al.* 2005c; 2005a), will be described in the next section, whereas a detailed comparison between the two architectures can be

```
FOR      $a IN norm
WHERE    textConstr ($a//paragraph//text(), 'health AND care')
AND      tempConstr ('vTime OVERLAPS PERIOD('2002-01-01','2004-12-31')')
AND      tempConstr ('eTime OVERLAPS PERIOD('2002-01-01','2004-12-31')')
AND      applConstr ('class_7')
RETURN   $a
```

Figure 3: An XQuery-equivalent query executable on our second system.

found in (Grandi *et al.* 2005b).

Semantic Versioning

The temporal multi-version model described above has then been enhanced in order to include a semantic versioning mechanism to provide personalized access, that is retrieval of all and only norm or their parts that are applicable to a given citizen according to his/her digital identity. Hence, the semantic versioning dimension encodes information about the applicability of different parts of a normative text to the relevant classes of the civic ontology defined in the infrastructure (O_C in Fig. 1). At the current stage of the research, semantic information is mapped onto a *tree-like* civic ontology, that is based on a taxonomy induced by IS-A relationships. The tree-like civic ontology is sufficient to satisfy basic application requirements as far as applicability constraints and personalization services are concerned, although more advanced application requirements may need a more sophisticated ontology definition.

For instance, the left part of Fig. 2 depicts a simple civic ontology built from a small corpus of norms ruling the status of citizens with respect to their work position. The right part shows a fragment of a multi-version XML normative text supporting personalized access with respect to this ontology. As we currently manage tree-like ontologies, this allows us to exploit the pre-order and post-order properties of trees in order to enumerate the nodes and check ancestor-descendant relationships between the classes. These codes are represented in the upper left part of the ontology classes in the Figure, in the form: (pre-order,post-order). For example, the class "Employee" has pre-order "3", which is also its identifier, whereas its post order is "6". The article in the XML fragment on the right-hand-side of Fig. 2 is composed of two paragraphs and contains applicability annotations (XML element *aa*).

Notice that applicability is inherited by descendant nodes unless locally redefined. Hence, by means of redefinitions we can also introduce, for each part of a document, complex applicability properties including extensions or restrictions with respect to ancestors. For instance, the whole article in the Figure is applicable to civic class "3" (attribute *applies_to*) and by default to all its descendants. However, its first paragraph is applicable to class "4", which is a restriction, whereas the second one is applicable to class "8" (attribute *applies_also*), which is an extension. The reconstruction of pertinent versions of the norm based on its applicability annotations is very important in an eGovernment scenario. The representation of extensions and restrictions gives rise to high expressiveness and flexibility in such a context.

Accessing the right version for personalization

The queries that can be submitted to the system can contain four types of constraints: temporal, structural, textual and applicability. Such constraints are completely orthogonal and allow users to perform very specific searches in the XML norm repository. Let us focus first on the applicability constraint. Consider again the ontology and norm fragment in Fig. 2 and let John Smith be a "self-employed" citizen (i.e. belonging to class "7") retrieving the norm: hence, the sample article in the Figure will be selected as pertinent, but only the second paragraph will be actually presented as applicable. Furthermore, the applicability constraint can be combined with the other three ones in order to fully support a multi-dimensional selection. For instance, John Smith could be interested in all the norms ...

- which contain paragraphs (*structural constraint*) dealing with health care (*textual constraint*), ...

- which were valid and in effect between 2002 and 2004 (*temporal constraint*), ...

- which are applicable to his personal case (*applicability constraint*).

Such a query can be issued to our system using the standard XQuery FLWR syntax (XQuery 2005) displayed in Fig. 3, where `textConstr`, `tempConstr`, and `applConstr` are suitable functions allowing the specification of the textual, temporal and applicability constraints, respectively (the structural constraint is implicit in the XPath expressions used in the XQuery statement). Notice that the temporal constraints can involve all the four available time dimensions (publication, validity, efficacy and transaction), allowing high flexibility in satisfying the information needs of users in the eGovernment scenario. In particular, by means of validity and efficacy time constraints, a user is able to extract consolidated current versions from the multi-version repository, or to access past versions of particular normative texts, all consistently reconstructed by the system on the basis of the user's requirements and personalized on the basis of his/her identity.

Implementation and performance evaluation

In order to test both the efficacy of the approach and the efficiency of the proposed technique, we built a prototype system implementing the data model. The system exploits

Query	Constraints				Selectivity	Performance (msec)	
	Tm	St	Tx	Ap		DOM-based	XML-Native
Q1	-	√	√	-	0.6%	2891	1046
Q2	-	√	√	-	4.02%	43240	2970
Q3	√	√	-	-	2.9%	47638	6523
Q4	√	√	√	-	0.68%	2151	1015
Q5	√	√	√	-	1.46%	3130	2550
Q1-A	-	√	√	√	0.23%	n/a	1095
Q2-A	-	√	√	√	1.65%	n/a	3004
Q3-A	√	√	-	√	1.3%	n/a	6760
Q4-A	√	√	√	√	0.31%	n/a	1020
Q5-A	√	√	√	√	0.77%	n/a	2602

Table 1: Features of the test queries and query execution time (time in milliseconds, collection C1)

an "XML-native" architecture, as it is composed of a Multiversion XML Query Processor designed on purpose, which is able to manage the XML data repository and to support all the temporal, structural, textual and applicability query facilities in a single component.

The prototype is implemented in Java JDK 1.5 and exploits ad-hoc data structures (relying on embedded "light" DBMS libraries) and algorithms which allow users to store and reconstruct on-the-fly the XML norm versions satisfying the four types of constraints. Such a component stores the XML norms not as entire documents but decomposed into a collection of ad-hoc temporal tuples, each representing one of their multi-version parts (i.e. paragraphs, articles, and so on); these data structures are then exploited to efficiently perform structural join algorithms (Al-Khalifa *et al.* 2002) we specifically devised and tuned for the temporal/semantic multi-version context. A detailed presentation of the proposed data structures and structural join algorithms, together with a related work discussion on these topics, is given in (Mandreoli, Martoglia, & Ronchetti 2006). Textual constraints are handled by means of an inverted index. The improvement with respect to our first temporal prototype are manifold:

- by querying ad-hoc and temporally-enhanced structures (which have a finer granularity than the entire documents managed by standard XML engines), our system is able to access and retrieve only the strictly necessary data;

- only the parts which are required and which satisfy the temporal constraints are used for the reconstruction of the retrieved documents;

- there is no need to retrieve whole XML documents and build space-consuming structures such as DOM trees to process a query.

Furthermore, the new architecture also provides support to personalized access by fast handling of the applicability constraints. Owing to the properties of the adopted pre- and post-order encoding of the civic classes, the system is able to very efficiently deal with applicability constraints during query processing by means of simple comparisons involving such encodings and semantic annotations.

As a consequence, we expected a high overall query processing efficiency together with low memory requirements.

In order to evaluate the performance of our system, we built a specific query benchmark and conducted a number of exploratory experiments to test its behavior under different workloads. The experiments have been effected on a Pentium 4 2.5Ghz Windows XP Professional workstation, equipped with 512MB RAM and a RAID0 cluster of two 80GB EIDE disks with NT file system (NTFS). We performed the tests on three XML document sets of increasing size: collection C1 (5,000 XML normative text documents), C2 (10,000 documents) and C3 (20,000 documents). In this section we will present in detail the results obtained on the collection C1, then we will briefly describe the scalability performance shown on the other two collections. The total size of the collections is 120MB, 240MB, and 480MB, respectively. In all collections the documents were synthetically generated by means of an ad-hoc XML generator we developed, which is able to produce different documents compliant to our multi-version model. For each collection, the average, minimum and maximum document size is 24KB, 2KB and 125KB, respectively.

Experiments were conducted by submitting queries of five different types (Q1-Q5). Table 1 presents the features of the test queries and the query execution time for each of them. All the queries require structural support (St constraint); types Q1 and Q2 also involve textual search by keywords (Tx constraint), with different selectivities; type Q3 contains temporal conditions (Tm constraint) on three time dimensions: transaction, valid and publication time; types Q4 and Q5 mix the previous ones since they involve both keywords and temporal conditions. For each query type, we also present a personalized access variant involving an additional applicability constraint (Ap constraint), denoted as Qx-A in the first column of Table 1.

Let us first focus on the "standard" queries. Our approach shows a good efficiency in every context, providing a short response time (including query analysis, retrieval of the qualifying norm parts and reconstruction of the results) of approximately one or two seconds for most of the queries. Notice that the selectivity of the query predicates does not impair performances, even when large amounts of documents containing some (typically small) relevant portions have to be retrieved, as it happens for queries Q2 and Q3. Our new system is able to deliver a fast and reliable performance in all cases, since it practically avoids

the retrieval of useless document parts. Furthermore, consider that, for the same reasons, the main memory requirements of the Multi-version XML Query Processor are very small, less than 5% with respect to "DOM-based" approaches such as the one adopted in (Grandi *et al.* 2003; Grandi, Mandreoli, & Tiberio 2005). Notice that this property is also very promising towards future extensions to cope with concurrent multi-user query processing, since memory requirements are not crucial for performance in the "XML-native" approach.

The time needed to answer the personalized access versions of the Q1–Q5 queries is approximately 0.5-1% more than for the original versions. Moreover, since the applicability annotations of each part of an XML document are stored as simple integers, the size of the tuples with applicability annotations is practically unchanged (only a 3-4% storage space overhead is required with respect to documents without semantic versioning), even with quite complex annotations involving several applicability extensions and restrictions.

Finally, we only make here a comment about the performance of our current prototype in querying the other two collections C2 and C3 and, therefore, concerning the scalability of the system. We ran the same queries of the previous tests on the larger collections and saw that the computing time always grows sub-linearly with the number of documents. For instance, query Q1 executed on the 10,000 documents of collection C2 (which is as double as C1) took 1,366 msec (i.e. the system was only 30% slower); similarly, on the 20,000 documents of collection C3, the average response time was 1,741 msec (i.e. the system was less than 30% slower than with C2). Also with the other queries the measured trend was the same, thus showing the good scalability of the system in every type of query context.

Conclusions and future work

In this paper, we presented the current achievements of an ongoing research activity we are carrying out in the context of a national research project in order to support efficient and personalized access to multi-version XML document repositories for eGovernment applications. We defined a data model supporting both temporal versioning and personalized access, built a prototype system implementing the data model and evaluated its performance through some exploratory experiments. Up-to-date results are very encouraging as to query response time, storage requirements and system scalability.

Our current research work is devoted to the extensions of this framework and to the development of the complete technological infrastructure enabling our approach to be self-contained and usable in a large Web-based eGovernment scenario. In particular, we plan to complete the infrastructure with the specification and implementation of the remaining auxiliary services described in the Introduction. Moreover, the adoption of a tree-like civic ontology –that is based on a taxonomy induced by the IS-A relationship– is sufficient to satisfy basic application requirements as far as applicability constraints and personalization services are concerned. However, more advanced application requirements include a more sophisticated ontology definition. As a matter of fact, we are currently working in extending the framework in order to fully support generic graph-like ontologies, containing, for instance, multiple interconnected IS-A taxonomies, PART-OF and equivalence relations between the classes. To this aim, the XML documents annotation scheme and their storage organization need to be enhanced. Further, we are also considering the use of new ad-hoc indexes on the semantic attributes to enhance the efficiency of the query processing algorithms even more for highly-selective applicability queries.

On the other hand, further work will also include the assessment of our developed systems in a concrete working environment, with real users and in the presence of a large repository of real legal documents. In particular, a civic ontology based on a corpus of real norms (concerning infancy schools) is currently under development.

Finally, as the reference ontology evolves in time due to modifications of the founding acts, we are trying to provide the ontology with a temporal versioning mechanism similar to the one we employed for XML documents. Furthermore, we also plan to extend our approach to a broader application range, by considering ontology-based personalization of generic Web resources.

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